Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz	)	GN Docket No. 17-183

COMMENTS OF BROADCOM LTD

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INTRODUCTION AND SUMMARY

As a leading Wi-Fi chip maker, Broadcom strongly supports the Commission's Notice of Inquiry ("NOI") seeking ways to expand flexible use of mid-band spectrum.[1] It is now widely recognized, by industry and policymakers alike, that the Commission must make more spectrum available for unlicensed use in order for Wi-Fi just to keep pace with ever-growing demand for wireless connectivity and to support emerging 5G use cases. Unlicensed spectrum continues to be the most effective tool for increasing wireless broadband access and for supporting increasing Internet traffic demand. Unlicensed technologies will become even more important as applications become more bandwidth intensive—but only if sufficient spectrum is available.

The band from 5925–7125 MHz ("the 6 GHz band") presents a perfect opportunity for the Commission to address the unlicensed spectrum shortfall. Because of the band's proximity to the core 5 GHz U-NII bands, the 6 GHz band would allow deep integration with, and expansion of, the existing 5 GHz unlicensed ecosystem. This will drive down the cost of equipment through economies of scale, simplify deployments, and allow consumers to move seamlessly from one band to the other, thereby improving efficiency.

The 6 GHz band plays an important role for fixed point-to-point services, which remain dynamic and productive, as well as for the important services provided by the Fixed Satellite Service ("FSS"), Broadcast Auxiliary Service ("BAS"), Cable Television Relay Service ("CARS"), and others. The Commission should therefore ensure that any action it takes in the 6 GHz band protects incumbents and is consistent with future growth in these services. Permitting

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[1] *Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, Notice of Inquiry, FCC No. 17-104, 32 FCC Rcd. 6373 (2017).

Wi-Fi in these frequencies can achieve this goal, without imposing any new coordination burdens on licensees, while dramatically increasing utilization of the band.

The 6 GHz band is therefore an optimal choice for a new unlicensed band to promote innovation and expand affordable connectivity. As a next step, the Commission should adopt a Notice of Proposed Rulemaking ("NPRM") that proposes to authorize expanded, flexible unlicensed use of the entire 6 GHz band to support broadband deployment. To maximize protections for incumbents and efficiency of unlicensed use, the Commission should seek comment on rules for four discrete 6 GHz sub-bands: 5925-6425, 6425-6525, 6525-6875, and 6875-7125 MHz. Each of these sub-bands includes different combinations of incumbents and, therefore, may require different approaches to spectrum sharing and interference protection. Where possible, the Commission should align 6 GHz rules in these proposed sub-bands with those in the 5 GHz bands to maximize efficiency.

I. BROADCOM PLAYS A CENTRAL ROLE IN EXPANDING WIRELESS BROADBAND.

As a leading diversified communications semiconductor company, Broadcom's product portfolio centers on four primary end markets: wired infrastructure, wireless communications, enterprise storage, and industrial markets. Due to our presence in this diverse set of markets, we have a unique understanding of the overall communications ecosystem and the various technologies used to transmit data. For example, Broadcom is an active member of leading communications standards and certification bodies, including the Institute of Electrical and Electronics Engineers ("IEEE"), the Third Generation Partnership Project ("3GPP"), and the Wi-Fi Alliance, and consistently plays a major role in advancing the state of the art in wireless technologies. Just this summer, Broadcom announced that it was sampling a complete ecosystem

of products implementing the latest generation of Wi-Fi, 802.11ax.[2] Wi-Fi chipsets form an important part of the wireless segment of Broadcom's business and are widely used by equipment vendors in commercial, enterprise, and consumer access points, as well as by client devices. In fact, Broadcom products and innovative solutions are so pervasive that they play an important role in enabling almost every wired or wireless communication at some point in the network.

Accordingly, Broadcom closely studies any opportunity for additional unlicensed spectrum in light of its unique view into the functioning of the broadband ecosystem and the needs of consumers. The comments below are the product of Broadcom's intensive analysis of the 6 GHz band and the unique benefits of 6 GHz for Wi-Fi.

II. UNLICENSED SERVICES ARE AT THE CORE OF TODAY'S WIRELESS ECONOMY.

Unlicensed spectrum has been the key ingredient in enabling the mobile broadband revolution, and remains the core of our connected economy. Unlicensed spectrum is unique in that it allows truly ubiquitous deployment in both public and private networks—ranging from large operator deployments in stadiums, to home networks that serve as the last-100-foot connection between consumers' devices and the Internet. Unlicensed spectrum puts wireless communications within reach of everyone, lifting restrictions on who can provide innovative new services, and where wireless technologies can be deployed.

Wi-Fi accomplishes this with incredibly high speeds, with low latency, and at low cost. The current Wi-Fi standard, 802.11ac, is capable of speeds of more than 1 Gbps. The emerging

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[2] Press Release, Broadcom, Broadcom Announces Availability of Industry's First Complete Ecosystem of 802.11ax Solutions (Aug. 15, 2017) http://investors.broadcom.com/phoenix.zhtml?c=203541&p=irol-newsArticle&ID=2293974.

version, 802.11ax, is faster still. Broadcom's 802.11ax chips are already capable of reaching up to 4.8 Gbps if sufficient spectrum is available.[3]

Unlicensed technologies—and Wi-Fi in particular—have generated a tremendous amount of economic value for consumers and the U.S. economy. Studies demonstrate that unlicensed technologies will contribute a total of $547 billion to the U.S. economy in 2017 alone, and add approximately $50 billion to the U.S. GDP.[4] This makes unlicensed spectrum a significantly larger contributor to national GDP than the entire U.S. rail transportation industry ($41.9 billion real value added), and approximately equal to the U.S. mining industry ($59.2 billion real value added).[5]

Well-crafted U.S. rules, and their widespread harmonization across the world, have led to a virtuous cycle of ever-increasing volumes, supporting massive economies of scale. Due to the low cost of Wi-Fi equipment, mobile carriers and Internet service providers increasingly rely on Wi-Fi to rapidly and inexpensively add capacity in response to growing consumer demand. By ensuring that sufficient unlicensed spectrum is available, the Commission will provide the platform that American innovators need to continue inventing new products and services.

Moreover, Wi-Fi usage is growing rapidly, giving rise to an urgent need for additional spectrum. Given its central role in broadband connectivity and the broader U.S. economy, making spectrum available for unlicensed use should be at the core of any national broadband

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3 *Id.*

4 Raul Katz, Telecom Advisory Servs., LLC, Assessment of the Future Economic Value of Unlicensed Spectrum in the United States 4 (Aug. 2014), http://wififorward.org/wp-content/uploads/2017/06/Katz-Future-Value-Unlicensed-Spectrum-final-version-1.pdf.

5 *See Industry Data*: *Value Added by Industry*, Bureau of Econ. Analysis (Apr. 21, 2017), https://bea.gov/iTable/iTable.cfm?reqid=51&step=51&isuri=1&5114=a&5102=1#reqid=51&step=51&isuri=1&5114=a&5102=1.

strategy. But, despite its vital role, Wi-Fi currently has access to only a small sliver of spectrum compared to licensed mobile wireless and other services. Wi-Fi carries nearly half of global Internet traffic[6] and 80% of mobile data,[7] using only 560 MHz of spectrum.[8] The Internet of Things, 5G, and emerging higher-bandwidth social media applications will likely cause this trend to accelerate, creating an even greater strain on unlicensed spectrum.

In addition, Wi-Fi is sometimes the *only* available connectivity option. For example, public Wi-Fi often plays a critical role in addressing the homework gap.[9] It also has been widely used to fill in connectivity gaps in the wake of natural disasters. For example, when hurricane Irma struck Florida, Puerto Rico, and the U.S. Virgin Islands, it caused massive mobile service outages. The Commission reported that Irma took as much as 80% of cell towers offline in the most heavily affected counties of Florida and Puerto Rico, and 90% in the U.S. Virgin Islands.[10] Wi-Fi providers stepped in to help, with Comcast opening up free public access to more than

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6 Cisco, Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 fig. 23 (Mar. 28, 2017), https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html.

7 Steve Methley & William Webb, Quotient Assocs. Ltd., Wi-Fi Spectrum Needs Study 13 (Feb. 2017), https://www.wi-fi.org/downloads-registered-guest/Wi-Fi%2BSpectrum%2BNeeds%2BStudy_0.pdf/33364.

8 The IEEE channel plan includes 60 MHz in the 2.4GHz bands and 500 MHz in the 5GHz bands.

9 *See Good-Bye Pay Phone, Hello Link!*, LinkNYC, https://www.link.nyc/ (last visited Oct. 2, 2017); Anton Troianovski, *The Web-Deprived Study at McDonald's*, The Wall Street J. (Jan. 28, 2013, 10:30 PM), http://www.wsj.com/articles/SB10001424127887324731304578189794161056954; Cecilia Kang, *Bridging a Digital Divide That Leaves Schoolchildren Behind*, The New York Times, Feb. 22, 2016, at A1, http://www.nytimes.com/2016/02/23/technology/fcc-internet-access-school.html?_r=0.

10 Communications Status Report for Areas Impacted by Hurricane Irma, FCC 4–11 (Sept. 11, 2017, 11:30 AM), http://transition.fcc.gov/Daily_Releases/Daily_Business/2017/db0911/DOC-346655A1.pdf.

137,000 of its Xfinity Wi-Fi hotspots throughout Florida.[11] Similarly, a Wi-Fi mesh network operated by the Red Hook Initiative played a central role in restoring connectivity in 2012 when hurricane Sandy badly damaged the Red Hook neighborhood of Brooklyn, with FEMA stepping in to expand access during the post-storm recovery.[12]

Wi-Fi also supports important industrial and infrastructure applications. UPS sorting facilities and Amazon.com fulfillment centers use Wi-Fi extensively to manage their operations.[13] Container terminals and railyards use Wi-Fi to coordinate their operations, ensuring that cargo can be transferred, routed, and moved safely and efficiently.[14] Retail providers often use Wi-Fi to orchestrate every phase of their supply chains from distribution centers to operations in their stores.[15]

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[11] Jennifer Earl, *Free Wi-Fi During Hurricane Irma: Comcast Opens Thousands of Hotspots*, CBS News (Sept. 7, 2017, 6:52 PM), https://www.cbsnews.com/news/hurricane-irma-comcast-free-wi-fi-hotspots-across-florida/.

[12] *Case Study: Red Hook Initiative WiFi & Tidepools*, New Am.: Open Tech. Inst. (Feb. 1, 2013), https://www.newamerica.org/oti/blog/case-study-red-hook-initiative-wifi-tidepools/.

[13] Laurie Mallis, *UPS Deploys New Scanning Device in Its Package Sorting Operation*, UPS Investor Relations (Aug. 2, 2012), http://www.investors.ups.com/phoenix.zhtml?c=62900&p=RssLanding&cat=news&id=1721740&pLibItem=1&localeId=73; Letter from Gerard J. Waldron, Counsel to Amazon.com Inc., to Marlene H. Dortch, Secretary, Federal Communications Commission, at ¶ 2, GN Docket No. 14-177 (filed Apr. 6, 2017).

[14] EF&I Servs. Corp, Lessons Learned: Making WiFi Work in Outdoor Industrial Environments (2012), http://www.eficorp.com/docs/whitepapers/OutdoorWiFi.pdf.

[15] *See, e.g.*, *Retail Wi-Fi Solutions*, Ruckus, https://www.ruckuswireless.com/solutions/retail (last visited Oct. 2, 2017); *Wi-Fi for Retail*, AT&T Business, https://www.business.att.com/enterprise/Service/wifi/industries-wifi/retail-wifi/ (last visited Oct. 2, 2017); Cisco, Transforming the Store Experience with Cisco Retail Solutions 1-6 (2014), https://www.cisco.com/c/dam/en_us/solutions/industries/retail/downloads/cisco-retail-solutions-brochure.pdf.

Wi-Fi and other technologies will be a crucial part of the 5G ecosystem. GSMA has recognized that "future networks will rely on a combination of mainstream and alternative technologies, and use both licensed and unlicensed spectrum, across different spectrum bands."[16] There is no single band or technology that will fulfill the promise of 5G. Industry's 5G transition requires an ecosystem of complementary and overlapping technologies, of which Wi-Fi will be a central component. In particular, Wi-Fi will likely continue to play the essential role it plays in today's mobile networks: densification. Wi-Fi is by far the most successful and proven technology for expanding network capacity. This is especially true in low-mobility environments, where demand for data is highly concentrated, such as in stadiums, airports, apartment buildings, mass transit, and other places where people congregate.

This is why the emerging 5G standards developed by 3GPP identify unlicensed technologies, including Wi-Fi, as peer radio access technologies in order to provide 5G mobile connectivity without any licensed component at all.[17] Broadcom has recently announced the next generation of Wi-Fi technology, designed from the ground up to support 5G services under the umbrella of the forthcoming 802.11ax standard, called Max WiFi. Max WiFi was specifically designed to provide a high-quality user experience with high speeds and low latency, even in extremely dense operating environments. Max WiFi can operate on 160 MHz channels to

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[16] Emeka Obiodu & Mark Giles, GSM Association, The 5G Era: Age of Boundless Connectivity and Intelligent Automation 10 (2017), https://www.gsmaintelligence.com/research/?file=0efdd9e7b6eb1c4ad9aa5d4c0c971e62&download.

[17] 3rd Generation P'ship Project, System Architecture for the 5G System, Tech. Report 3GPP TS 23.501 (draft V1.4.0), https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3144.

provide the throughput necessary to support emerging applications, such as widespread use of virtual or augmented reality and HD video.[18]

Technologies like Max WiFi are helping to push spectral efficiency to the limit and achieve the best wireless connectivity possible under existing constraints. But, as Chairman Pai has recognized, the Commission "must free up . . . more unlicensed spectrum for things like Wi-Fi."[19] However, instead of making more mid-band spectrum available for Wi-Fi, the United States has taken a step in the opposite direction. The Commission's recent decision, in consultation with the National Telecommunications and Information Administration, to cease work on sharing rules to allow unlicensed to operate alongside federal incumbents in U-NII-2B closed off one of the few remaining avenues for expanding unlicensed mid-band spectrum, other than through this NOI. A recent study reveals that Wi-Fi will need access to an additional 500 MHz in the next two years to keep up with demand, and up to another 1 GHz by 2025.[20]

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[18] *See* Press Release, Broadcom, *supra* note 2*; How Does Max Work? The Latest Evolution of Wi-Fi*, Max WiFi, http://maxwifi.org/how-max-works/ (last visited Oct. 2, 2017); *Wi-Fi Vantage*, Wi-Fi Alliance, https://www.wi-fi.org/discover-wi-fi/wi-fi-vantage (last visited Oct. 2, 2017).

[19] *Ajit Pai, FCC Chairman Bio*, FCC, https://www.fcc.gov/about/leadership/ajit-pai (last visited Oct. 2, 2017); *see also* Commissioner Michael O'Rielly, *A Mid-Band Spectrum Win in the Making*, FCC Blog (July 10, 2017), https://www.fcc.gov/news-events/blog/2017/07/10/mid-band-spectrum-win-making ("Study after study has shown that the U.S. is going to need multiple gigahertz of licensed and unlicensed spectrum just to keep up with current growth patterns."); Commissioner Jessica Rosenworcel, *Bringing the Connected Future to All Americans, May 11, 2012 – January 3, 2017*, FCC Blog (Dec. 30, 2016), https://www.fcc.gov/news-events/blog/2016/12/30/bringing-connected-future-all-americans-may-11-2012-%E2%80%93-january-3-2017 ("Moreover, as any wireless user can attest to, the airwaves used for Wi-Fi today are getting crowded—putting a premium on identifying additional spectrum for unlicensed growth.").

[20] Methley & Webb, *supra* note 7, at 29.

III. THE 6 GHZ BAND IS AN IMPORTANT OPPORTUNITY TO MAKE NEEDED SPECTRUM AVAILABLE FOR UNLICENSED SERVICES.

The 6 GHz band's close proximity to the 5 GHz U-NII bands, which are globally harmonized for unlicensed use, makes it ideal for meeting users' wireless data demand. Synergies between 5 and 6 GHz Wi-Fi would allow each to become more valuable than it ever could be in isolation, as long as the Commission's 5 and 6 GHz unlicensed technical rules are broadly compatible. Most importantly, Wi-Fi throughout the 6 GHz band could be integrated into unified 5/6 GHz chipsets, much as Broadcom and other manufacturers today integrate U-NII-1 and U-NII-3 capabilities. This would quickly allow unlicensed 6 GHz chipset manufacturers to leverage the massive economies of scale that characterize the 5 GHz Wi-Fi ecosystem, and which keep costs very low for both operators and consumers. In fact, the forthcoming 802.11ax standard is in the process of being modified to accommodate potential 6 GHz operations,[21] meaning that there would also be no need for a lengthy new standards setting process before 6 GHz Wi-Fi could reach the market. Much of the work to put 6 GHz Wi-Fi into the hands of consumers is already being done.

Similarly, 6 GHz spectrum has propagation characteristics that closely resemble 5 GHz spectrum. This means that industry practices, scale, and sophistication relating to network topologies, deployment guidelines, and other forms of professional expertise could be brought to bear in the deployment of 6 GHz Wi-Fi networks.

The proximity of these two bands, and the potential for integrated 5/6 GHz chipsets, would also mean that traffic could be efficiently steered from one band to another as conditions warranted. This would allow both 5 and 6 GHz spectrum to be used more efficiently by ensuring

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[21] *See* Rich Kennedy, Abstract, *IEEE P802.11 Wireless LANs: P802.11ax PAR Modification* (July 12, 2017), https://mentor.ieee.org/802.11/dcn/17/11-17-0913-02-00ax-par-modification-to-support-6-ghz-band.docx.

that each user is assigned to the clearest channel in a given location, and promoting the use of wider channels to increase speeds and reduce latency. In addition, since properties of 6 GHz spectrum are similar to 5 GHz spectrum, operators could re-use same deployment architectures and re-use existing metrics across both bands.

Permitting robust unlicensed operations is also likely the only viable option for significantly increasing utilization of the 6 GHz band without undermining incumbents. Parts of the 6 GHz band are heavily used today in some geographic areas, and it is an important band for fixed point-to-point services. It is essential to protect these and other licensed services in the band, and to allow these services to continue to grow. Wi-Fi would be an ideal complement to these licensed services, which are typically outdoor and highly directional. Wi-Fi could make intensive use of this spectrum without causing harmful interference to incumbent services. Several sharing techniques can achieve this goal and the Commission should seek comment on which is the best choice for each of four 6 GHz sub-bands, as described below.

Each portion of the 6 GHz band is used by a number of important licensed incumbents, making complementary unlicensed use a more promising approach than displacing these licensees. Fixed Service ("FS") use, for example, is very significant throughout the band, not just in the lower part of the band.[22] A new licensed mobile service in the upper part of the band would therefore face significant challenges maintaining the quality-of-service guarantees that mobile operators typically require, without dramatic steps such as clearing the band of incumbent licensed services, or precluding any expansion of incumbent services. The fact that there are existing licensed mobile operations in certain portions of 6425-7125 MHz would raise similar and perhaps more significant challenges for a new licensed service in those frequencies.

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[22] *See infra* p. 14.

There are likely only two possible approaches to permitting a new licensed mobile service in either 5925-6425 MHz or 6425-7125 MHz that would allow a licensee to achieve the guaranteed quality of service that cellular operators require. First, the band could be cleared of incumbents entirely and licensees repacked into other, already crowded bands. Second, existing licensees could be grandfathered and allowed to stay but not grow or change. Without such measures, a licensee in an existing 6 GHz service could disrupt a new mobile licensee's operations by simply registering a new fixed link. However, both of these approaches would cause serious harm to existing licensees, preventing any new use of these bands by the existing licensed services, or potentially increasing interference by compressing a large number of existing licensees into a significantly smaller swath of spectrum that is already used heavily.

By contrast, Wi-Fi could coexist alongside these incumbents, providing a much-needed boost to Wi-Fi capacity without undermining incumbent operations. Wi-Fi can readily protect and share with FS links, since FS links operate with pencil beamwidths, outdoors, at relatively high transmit power levels, and detailed technical characteristics of these links are publicly available. Wi-Fi, on the other hand, is primarily used indoors at low power levels. Similarly, Wi-Fi has a strong track record of sharing with incumbent FSS uplink licensees in other bands.

IV. THE COMMISSION SHOULD PROPOSE A 6 GHZ BAND STRUCTURE THAT PERMITS DIFFERENT TECHNICAL RULES TO ADDRESS DIFFERENT INCUMBENT OPERATIONS.

As Figure 1 illustrates, in addition to FS and FSS there are several other services in these bands that require protection, including mobile BAS and CARS, which are present in different combinations in different parts of the band. Accordingly, the most efficient and effective mechanism for protecting incumbents will likely vary at different frequencies. The Commission should therefore propose 6 GHz rules that permit it to apply the right interference-protection

tools to the right parts of the band. Conversely, it should avoid imposing a single set of one-size-fits-all rules across the entire band because this over-regulation would unnecessarily hamper efficient spectrum use and investment.

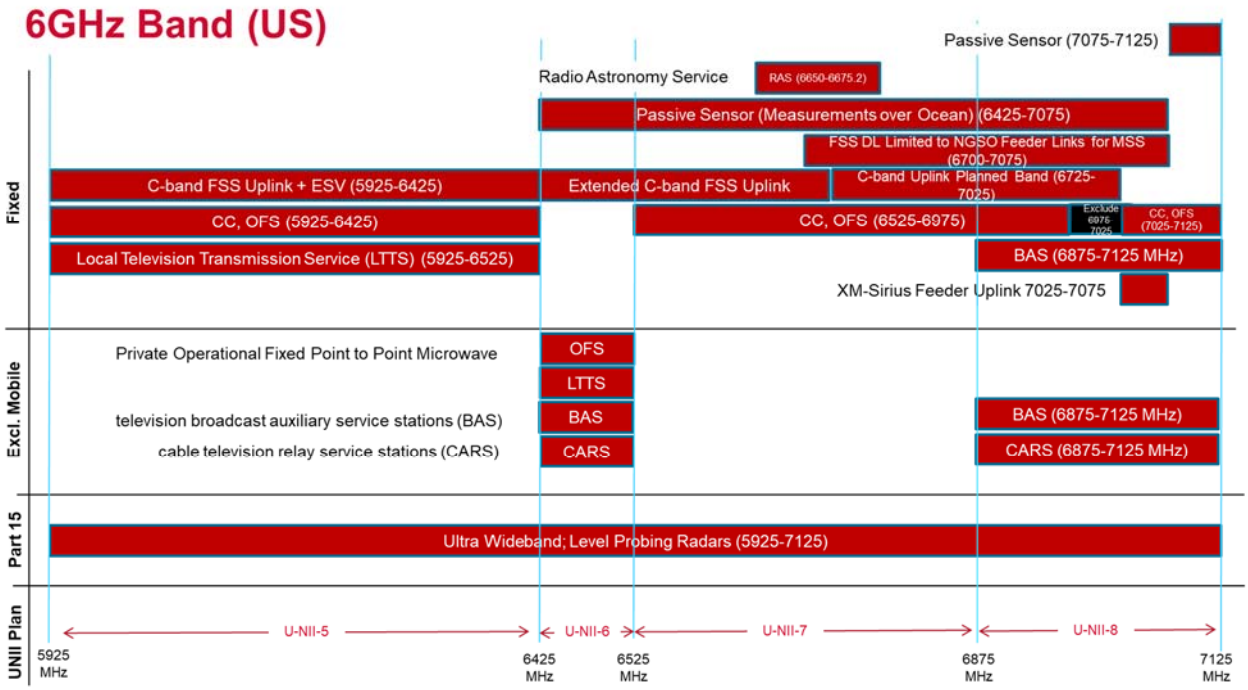


Figure 1 — 6 GHz Incumbents and Proposed Sub-Bands

To avoid this inefficient result, the Commission should propose to create four new 6 GHz U-NII bands, to correspond to segments of the 6 GHz band with different incumbent uses and interference-protection needs:

U-NII-5 — 5925-6425 MHz

U-NII-6 — 6425-6525 MHz

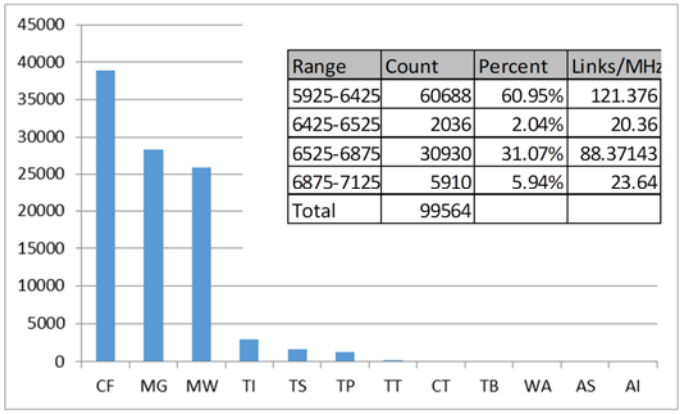
U-NII-7 — 6525-6875 MHz

U-NII-8 — 6875-7125 MHz

As Figure 1 illustrates, these sub-bands primarily serve to separate portions of the 6 GHz band that contain licensed mobile incumbents from those which do not. The proposed U-NII-6 band in

particular is almost exclusively licensed terrestrially for mobile operations. This is an important distinction given the probability that mobile users will require different types of interference protection than fixed services. This proposed band segmentation would maximize utility for unlicensed operations, while ensuring that existing licensed services, including future licensees, are robustly protected.

In addition to the different incumbent services in each of these sub-bands, these boundaries also reflect differences in the typical use of spectrum, even by licensees operating under the same types of radio service allocation. To better understand the current terrestrial users in the 6 GHz band, Broadcom conducted a detailed review of the data contained in the Commission's Universal License System ("ULS") as of March 21, 2017.[23] This review found that the vast majority of licensed links are attributable to the Common Carrier, Microwave Industrial Business Pool, and the Microwave Safety Pool services as outlined in Figure 2 below.



Range	Count	Percent	Links/MHz
5925-6425	60688	60.95%	121.376
6425-6525	2036	2.04%	20.36
6525-6875	30930	31.07%	88.37143
6875-7125	5910	5.94%	23.64
Total	99564		

Code	Description	Regulation
AI	Aural Intercity Relay	BAS, Part 74
AS	Aural Studio Transmitter Link	BAS, Part 74
CF	Common Carrier Fixed Point to Point Microwave	Part 101
CT	Local Television Transmission	Part 101, Subpart J
MG	Microwave Industrial / Business Pool	Part 101, Eligibility Part 90
MW	Microwave Public Safety Pool	Part 101, Eligibility Part 90
TB	TV Microwave Booster	BAS, Part 74
TI	TV Intercity Relay	BAS, Part 74
TP	TV Pickup	BAS, Part 74
TS	TV Studio Transmitter Link	BAS, Part 74
TT	TV Translator Relay	BAS, Part 74
WA	Microwave Aviation	Part 101, Eligibility Part 87

Figure 2—Analysis of the links listed in the ULS as of March 21, 2017 according to service

[23] Note that this review excluded CARS licenses, which are authorized in the 6425-6525 MHz and 6875-7125 MHz bands. CARS is not licensed on an individual link basis, and which uses a separate licensing database.

These ULS links are distributed across the 6 GHz band as indicated in Figure 3 below. Common Carrier, Microwave Industrial Business Pool, and Microwave Public Safety Pool operate primarily in U-NII-5 and U-NII-7. BAS, Microwave Public Safety Pool, and Microwave Industrial Business Pool operate in U-NII-6, and BAS, Microwave Public Safety Pool, and Common Carrier operate in U-NII-8.

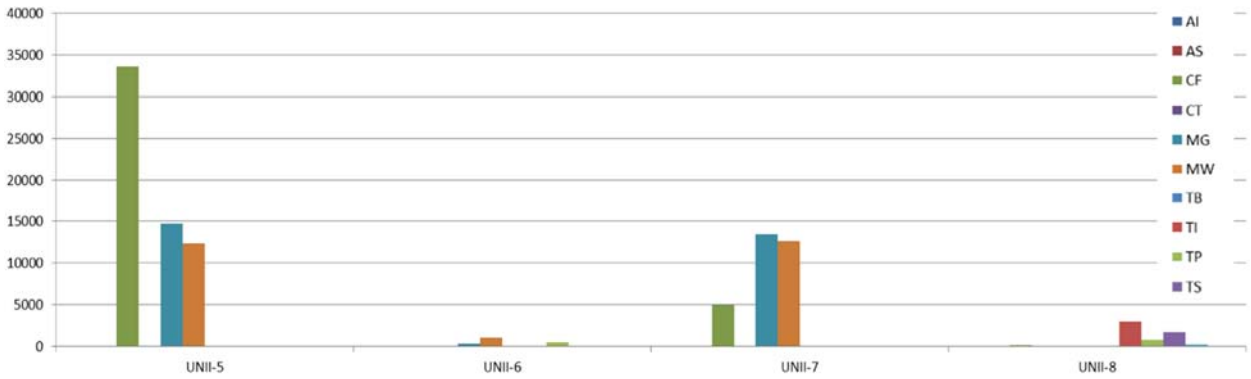


Figure 3—Number of Links listed in ULS by Band

This already illustrates significant variation in incumbent use by band. However, these services operate links that occupy a variety of bandwidths ranging from 400 KHz to 60 MHz. Therefore, to better understand the relative density of spectrum use by each of these services, Broadcom analyzed the number of links authorized to operate in every 0.5 MHz increment of the 6 GHz band, as depicted in Figure 4.

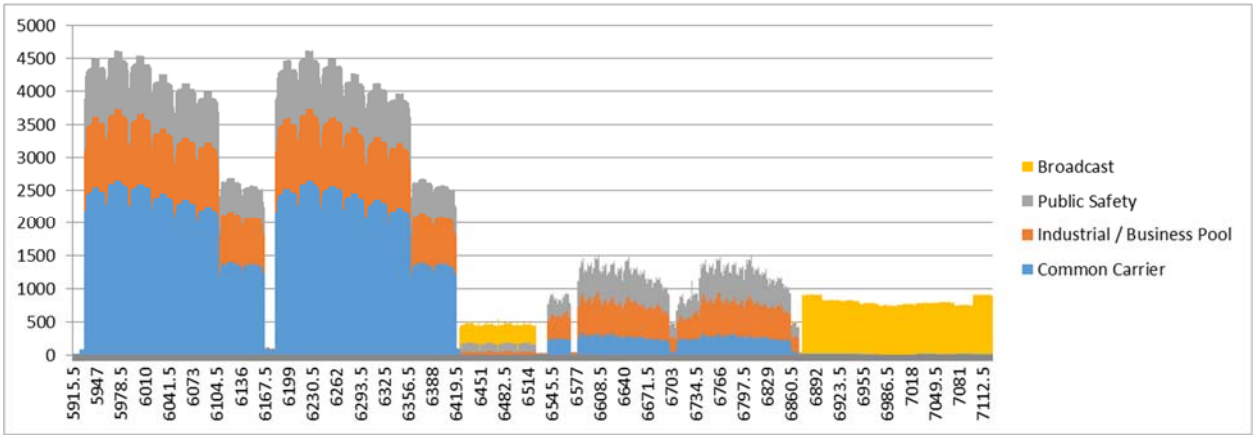


Figure 4—6 GHz Spectrum Usage in the United States by Frequency and Service Type as listed in ULS[24]

This analysis led Broadcom to the conclusion that FCC rules that establish four 6 GHz U-NII sub-bands would be the most effective approach by permitting tailored interference protections for each service, while minimizing unneeded regulations. Note that this analysis does not include CARS licensees, which are not listed in ULS and are authorized to operate in U-NII-6 and U-NII-8.

The typical height, beamwidth, gain, and beam steering characteristics of the antennas used for these links also vary significantly across these sub-bands. These technical characteristics may also play a significant role in shaping potential sharing rules, reinforcing the need for four 6 GHz U-NII sub-bands.

In particular, antenna gain and beam pattern play a significant role in determining a receiver's potential sensitivity to different types of interference. Typically, a high-gain antenna serves to magnify any signal—both the desired signal and interference—within a narrow area, while substantially reducing interference received from other directions. On the other hand, a

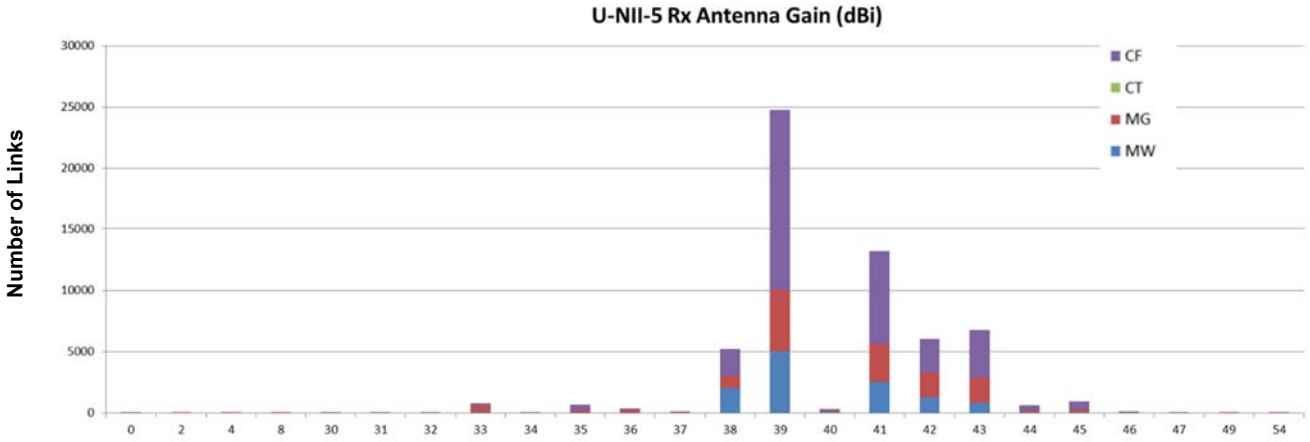
[24] For the purposes of this graph, all of the BAS services are described as "broadcast." In some cases, licensees registered links in channels or bands that overlap within very limited frequency ranges. These cases were omitted for clarity.

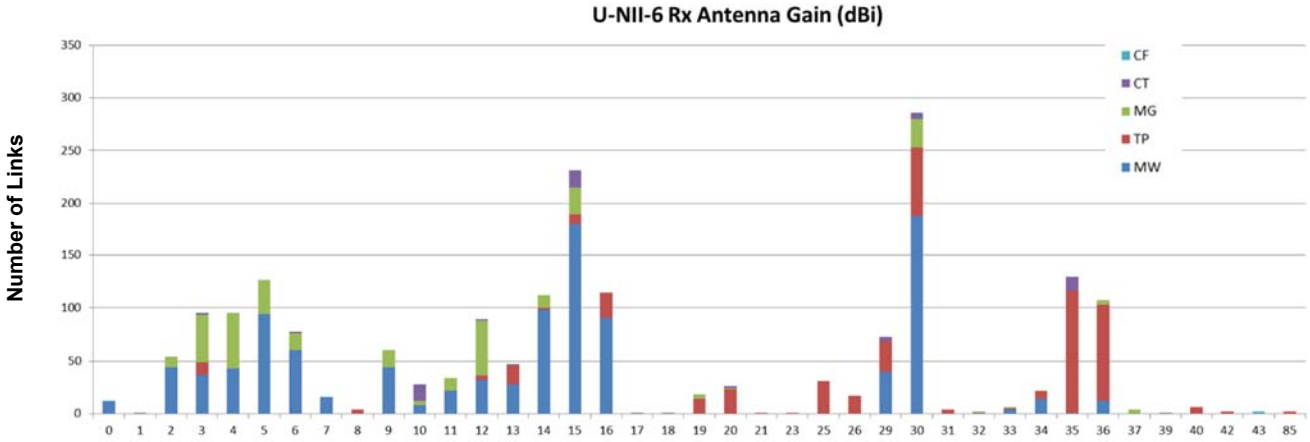
low-gain antenna neither significantly magnifies nor suppresses interference that is received in any particular direction.

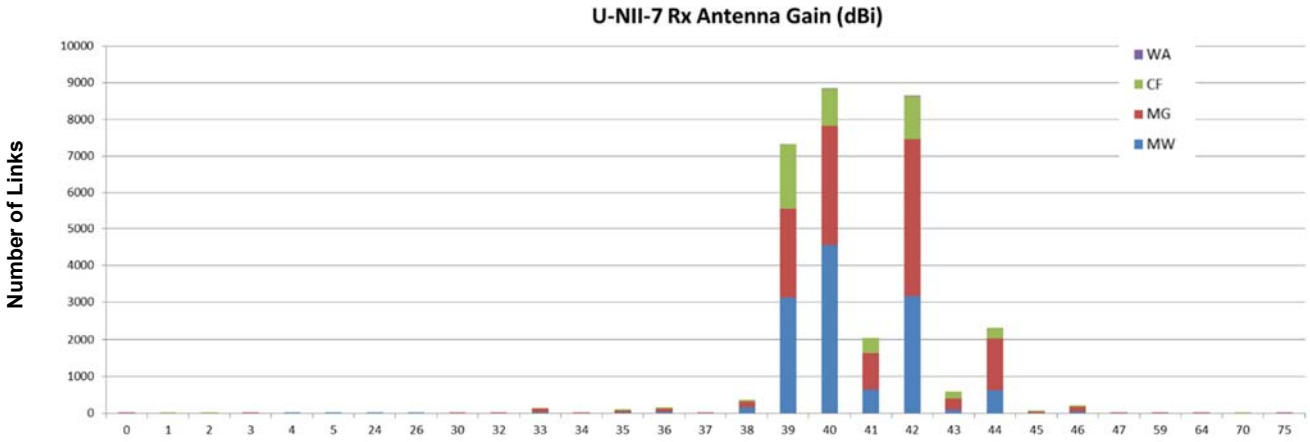
For high-gain fixed receiver antennas, the receiver's sensitivity to interference in any given direction can be determined based on ULS licensing data, which includes the necessary antenna information. This information and, correspondingly, the angular location of an interfering source with respect to the antenna, is of at least equal importance in preventing interference as the distance between the interfering source and the antenna. For mobile 6 GHz services, however, high-gain antennas must be steerable, making it more challenging to use this angular separation information to prevent harmful interference.

In addition, the transmit power and segment length of each link, together with the transmitter and receiver antenna gains, are the fundamental parameters that determine link margin. Receivers that are operating with high link margin are less susceptible both to channel fading (where the path loss of the link increases, e.g. due to heavy rain) and interference that may be caused by other sources.

As depicted in Figure 5, the receiver antenna gain distribution for U-NII-5 and U-NII-7 are largely the same, with the majority of receivers operating between 38 and 44 dBi antenna gain. The antenna gain for receivers used in the U-NII-6 band is far more diverse and associated with the various functions of the mobile equipment in that band. The antenna gains for U-NII-8 are closer in distribution to U-NII-5 and U-NII-7, but have a wider range because of some of the mobile BAS equipment in that band.


U-NII-5 Rx Antenna Gain (dBi)
Number of Links
30000
25000
20000
15000
10000
5000
0
CF
CT
MG
MW
0 2 4 8 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 49 54


U-NII-6 Rx Antenna Gain (dBi)
Number of Links
350
300
250
200
150
100
50
0
CF
CT
MG
TP
MW
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 23 25 26 29 30 31 32 33 34 35 36 37 39 40 42 43 85


U-NII-7 Rx Antenna Gain (dBi)
Number of Links
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
WA
CF
MG
MW
0 1 2 3 4 5 24 26 30 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 59 64 70 75

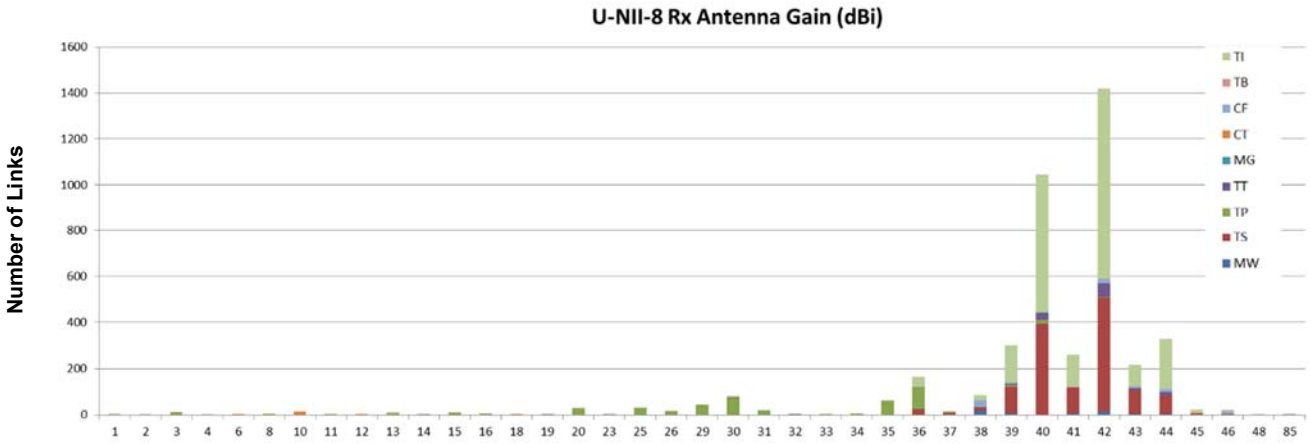
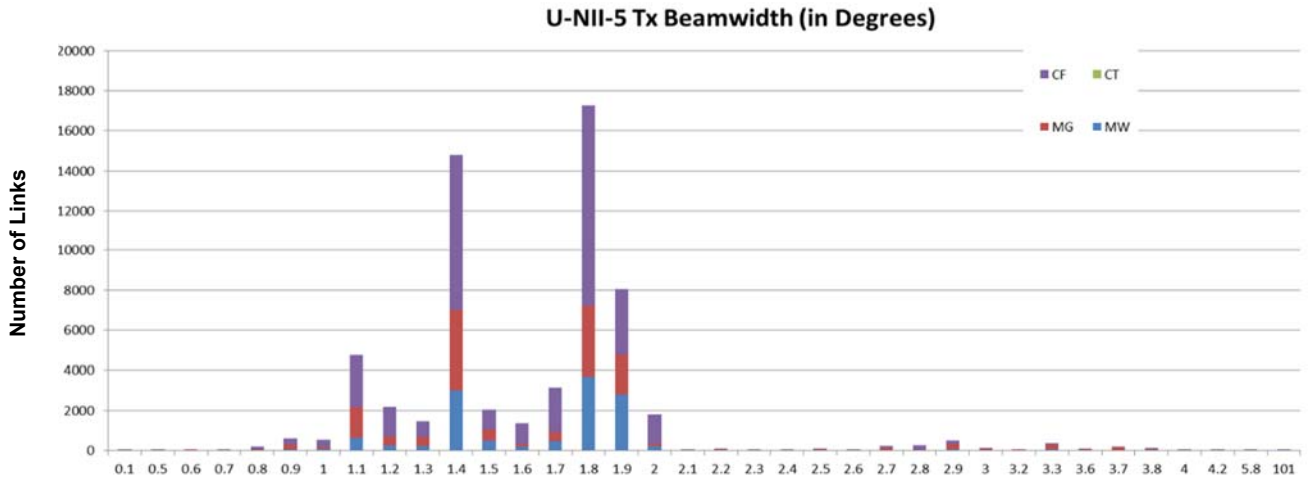


Figure 5—Count of Links by Receiver Antenna Gain (dBi)

As depicted in Figure 6, the majority of the links in U-NII-5 and U-NII-7 bands have beamwidths of less than 2 degrees. Most of the links in U-NII-6 have beamwidths of more than 5 degrees, and the majority is listed as having 360-degree beamwidth. U-NII-8 has both fixed and mobile use, and so has equipment operating with a combination of the beamwidths associated with the other sub-bands.



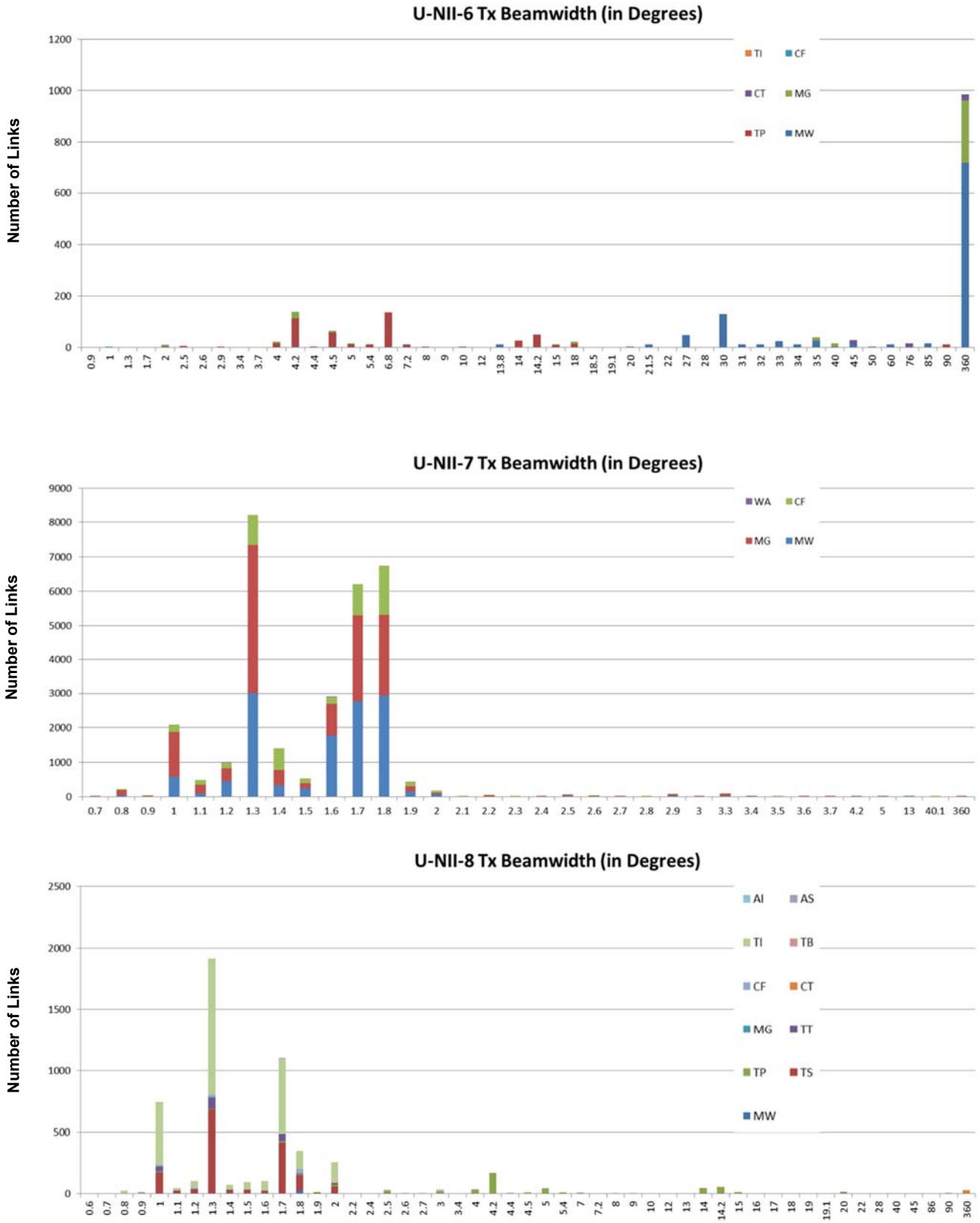
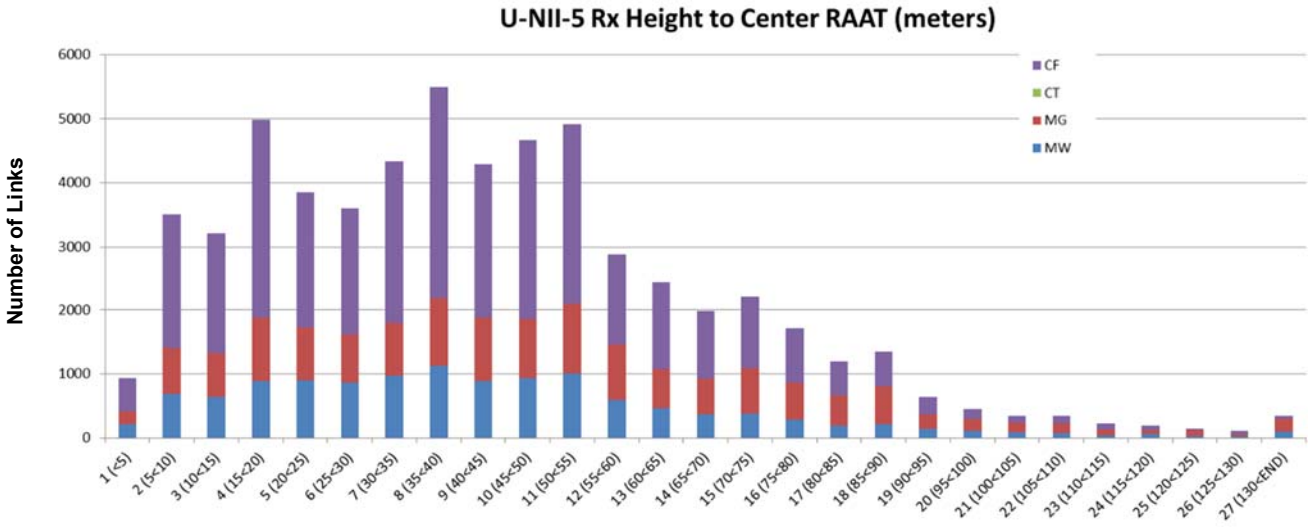


Figure 6—Count of Links by Transmit Beamwidth in Degrees

As with the other characteristics, as depicted in Figure 7, the antenna height distributions are similar for U-NII-5 and U-NII-7. U-NII-6 antenna height distribution is heavily weighted towards the 5-10 meter range and the over-130-meter height range. U-NII-8 distributions are a mix of those found in the other sub-bands. Antenna heights and associated downtilt/uptilt can have a significant impact on the amount of aggregate interference into the receiver. For example, high-gain receiving antennas that are mounted high above ground level significantly attenuate interference that may originate from the region directly below the antenna. On the other hand, receiving antennas that are mounted closer to ground level will typically receive lower levels of interference from sources that originate in regions further away from the antenna due to greater ground clutter path loss. In addition, receive antennas that tilt upwards will typically be less susceptible to interference originating at the same or lower heights.



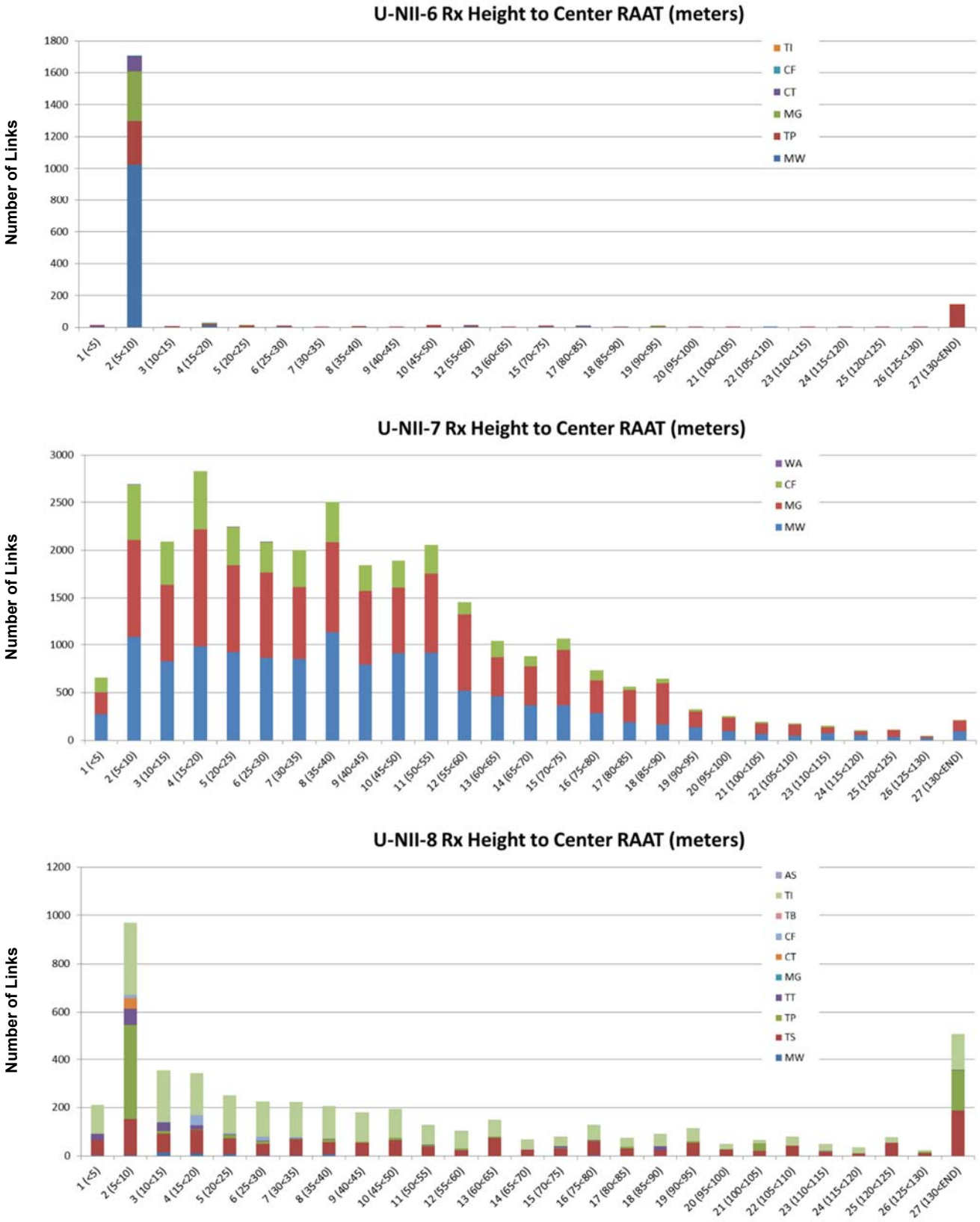
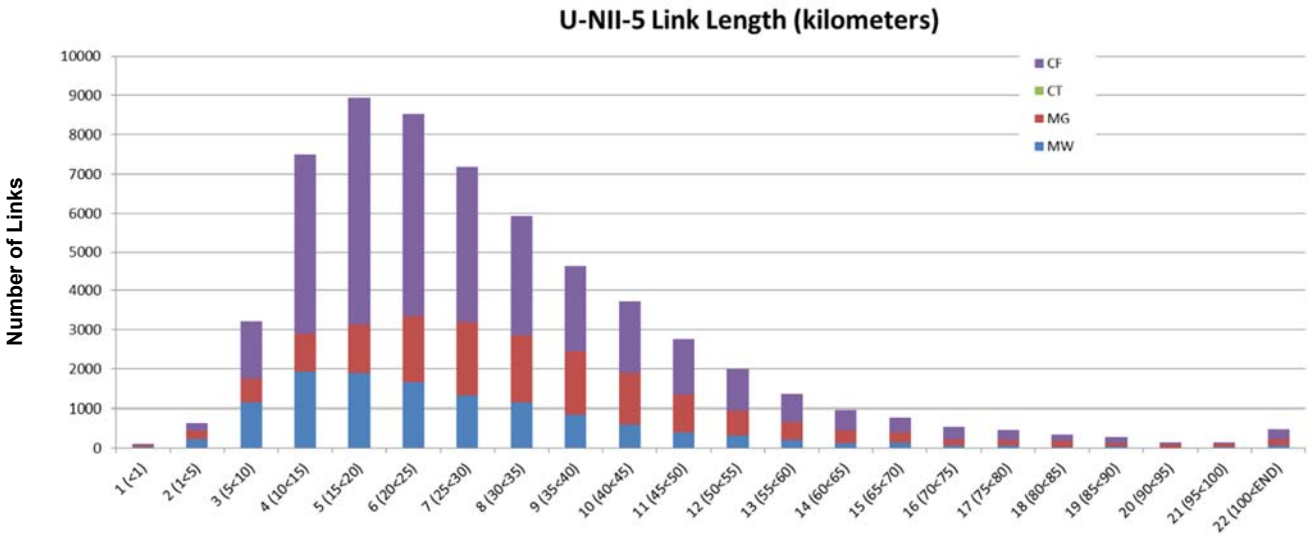
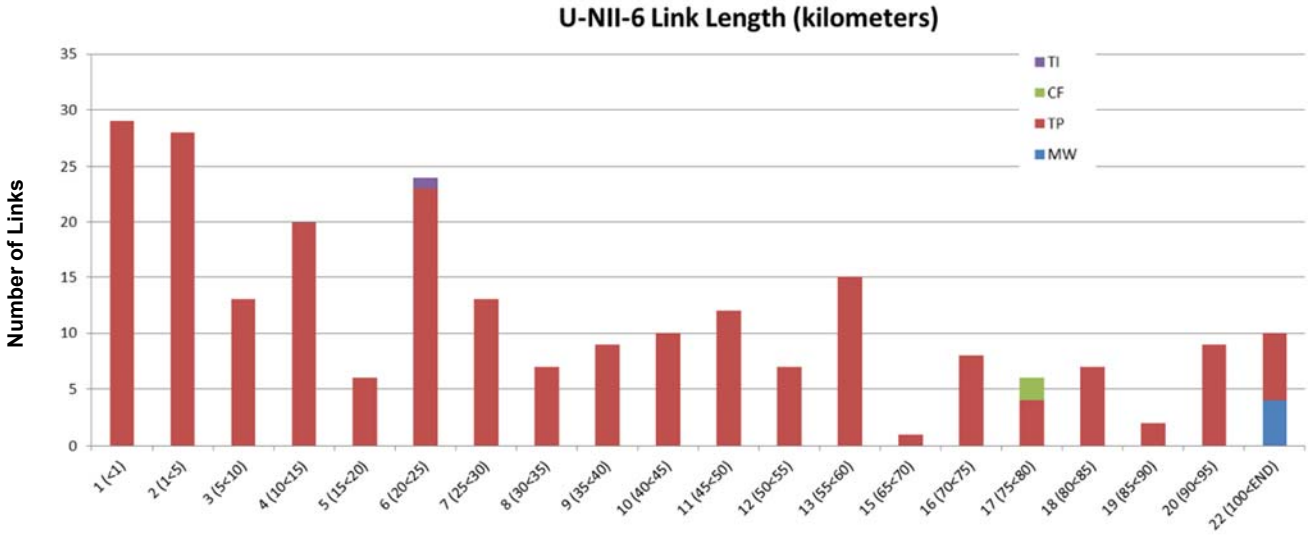


Figure 7—Receiver Antenna Height (Bins of 5 Meter Increments)

As with the other characteristics, as depicted in Figure 8, the segment-length distributions are similar for U-NII-5 and U-NII-7. The segment lengths in U-NII-6 are longer, which is associated with the maximum distance at which a mobile station transmitter can travel from the fixed receiver. U-NII-8 distributions are a mix of those found in the other sub-bands because it contains both fixed and mobile links.





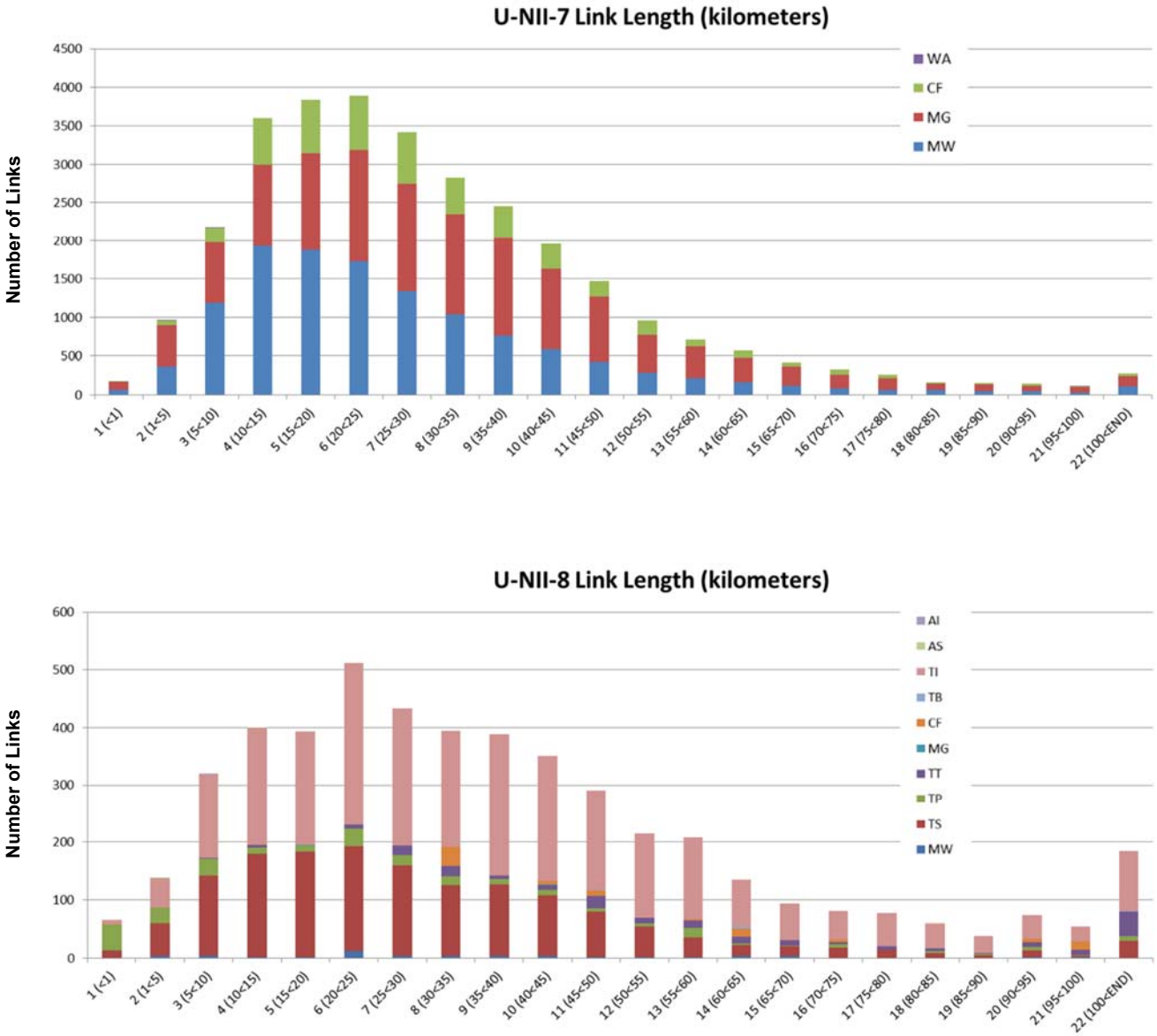


Figure 8—Link Segment Length (Bins of 5 KM Increments)

Not every factor will individually play a decisive role in developing technical rules for potential unlicensed operations. But, together, they provide further indications of the real differences in each sub-band, supporting a framework that allows different co-existence rules for each frequency range.

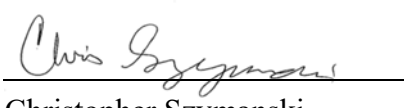
The Commission, and unlicensed technologies, have a number of tools in their toolbox to protect these incumbent services while promoting intensive unlicensed use. For example, the Commission should seek comment on the possible role of different sets of rules for indoor and outdoor operations, as the Commission has implemented in the 5GHz U-NII-1 band.[25] Similarly, it should ask about the potential utility of rules that allow devices the flexibility to operate at lower power levels instead of implementing a more complex coexistence system, if the Commission decides that such a system is necessary in one or more 6 GHz sub-bands. As it does so, the Commission should seek to maximize compatibility between 5 GHz and 6 GHz U-NII rules. Rules that are consistent between the two bands will reduce costs for consumers and further accelerate deployment of 6 GHz Wi-Fi.

[25] *See* 47 C.F.R. § 15.407(a)(1).

CONCLUSION

Access to additional mid-band spectrum is critical to addressing the unlicensed spectrum crunch. The NOI has identified 6 GHz as an ideal band to address the significant and growing spectrum shortfall facing unlicensed services. The Commission can best harness the potential of this band by designing a structure that can protect licensees from harmful interference while supporting investment and greater utilization. To do so, the Commission should issue a NPRM that: (1) proposes to enable unlicensed broadband operations from 5925-7125 GHz, with (2) interference-protection mechanisms appropriate to different incumbent operations within the frequency range, through four sub-bands, and (3) seek comment on how, to the maximum extent practicable, the rules can be aligned with neighboring 5 GHz U-NII rules. Broadcom thanks the Commission for addressing this important issue, and stands ready to assist in any way it can.

Respectfully submitted,



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